Gender and Information Technology: The Math Challenge

Denise Shortt
(dshortt@ryerson.ca)

Wendy Cukier
(wcukier@ryerson.ca)

Sarah Inkpen
(inkpen@rogers.com)

Ken Grant
(kagrant@ryerson.ca)

School of Information Technology Management
Ryerson University
350 Victoria St.
Toronto, Ontario,
M5B 2K3, Canada

Abstract

This paper examines the impact that mathematics admission requirements may have on female enrolments in information technology programs and by extension IT professions. Recent research has called into question the use of mathematics as a necessary requirement and essential predictor of success in IT programs and professions. In the context of the evolving multidisciplinary nature of the IT industry and the resulting broadening skill set required for success in IT, it has been suggested that multiple entry points should be encouraged and accepted. Specifically, this paper focuses on a university undergraduate program in information technology management that saw a significant drop in female enrolment when mathematics was introduced as a mandatory requirement. In response, the university developed a pilot study to further analyze this change in participation rate and to determine if the math requirement was serving as an unintended barrier to entry for female students. The pilot program was also intended to increase alternative points of entry to IT for students with nontraditional backgrounds. This paper outlines the design of the pilot project and provides a preliminary report of findings as well as suggested plans for a future long-term study. The results of the pilot raises some questions that should be of interest to educators especially those interested in gender equity and who may be involved in admission policy and/or curriculum design and development.

Keywords: Gender, Information Technology, Mathematics, Education

1. INTRODUCTION

Motivated by concerns about the shortage of skilled IT workers, as well as interest in equity issues, a number of studies have explored the barriers to women's participation in IT professions. Generally such studies have tended to define IT professions as synonymous with computer science and engineering and have focused on the decline in female enrolment in computer science and engineering programs (Whittaker, 2000). Studies around the world have examined a wide range of contributing factors (Trauth et. al. 2000; Frize and Deschenes, 1999; Fountain, 1999; University of Limerick, 1998; Turkle, 1995; Cukier, 1993; CAEB, 1991). Typically these have emphasized ways to increase the participation of women in computer science and engineering and have stressed the importance of developing female role models, reducing stereotypes and encouraging girls in math and science at an early age. Most of the work to date, even by feminists, has accepted the prevailing idea that 'information technology' is virtually synonymous with engineering and computer science even though there is compelling evidence that IT is much broader and requires a wide range of skills. For example, one study revealed that women accounted for 15% of students in computer science, 16% in electrical engineering, 35% in information technology management, 44% in new media and 56% in business management. Gender splits in faculty were similar (Cukier and Devine, 2001).

While there has been considerable research on barriers to women's participation, particularly forms of overt discrimination, less work has been done on systemic and institutional forms of discrimination, the unintentional, ‘taken-for-granted’ artifacts of institutionalized values, beliefs and behaviour. An important form of institutional discrimination "is the existence of requirements, which are not essential to performance and have the unintended consequence of excluding certain groups" (Ontario Human Rights Code, 1999). When considered in the context of the IT profession, the issue of mathematics as an entry point to studying IT has been called into question. Educators have been urged to: “Respect multiple points of entry. Different children will encounter different entry points into computing – some through art, for example, some through design, some through mathematics. These multiple entry points need to be respected and encouraged, while we remain sensitive to activities and perspectives that are appealing to girls and young women” (AAUW, 2000). Consequently, there is merit in examining the almost sacrosanct assumption that advanced mathematics is an essential requirement or predictor of performance in IT programs and careers. This notion has been reinforced by the assumption that IT is synonymous with computer science and engineering.

Considerable research has been conducted into differences in male and female attitudes to mathematics in terms of proficiency, preference, (AAUW, 1991) confidence, (Toronto Board of Education, 1996), as well as female friendly pedagogical approaches (AAUW, 1991). “All students’ enthusiasm for mathematics declines as they get older, but the loss of interest among girls is significantly greater. The percentage of girls who like mathematics drops 20 points to 61 percent by high school. The number of boys drops 12 points to 72 percent. And the gap between girls and boys who like mathematics increases 3 points to 11 points” (AAUW, 1991). Student interest has been shown to have considerable impact on achievement in math related courses and in determining whether students continue study in mathematics (Ma and Willms, 1999). In particular, female students have been found to express negative attitudes toward mathematics and in their own ability. The issue of mathematics proficiency as the principal indicator of success in information technology academic programs is one area for further exploration.

The effectiveness of using mathematics as an entry requirement for computer science students has also been questioned (Grundy, 2000).

> One of the criteria often set for admitting people to computer science is whether they can think in the abstract and whether they can express abstract ideas. Matriculation level mathematics was once a requirement for entry to most undergraduate computing courses because it was considered to be evidence of skill in abstract thinking and handling mathematical symbolism. The major reason this requirement has been largely dropped is that it only measured skill in some types of abstraction involved in computing but by no means all of them. People who had shown proficiency at matriculation level mathematics were not necessarily good at dealing with the non-mathematical abstractions in computing and, conversely, students could be proficient in the areas of non-mathematical abstraction in computing without necessarily being good at mathematics. (Grundy, 2000, p.5)

It has been suggested that approaches to mathematics, which focus on abstraction rather than practical application, tend not to suit women. "The conventional style of teaching mathematics, particularly at higher levels, is one which is likened to a universal truth [being handed down by some disembodied, non-human force]" (Becker, 1995, p.168). It has also been argued that there is a political dimension to the use of mathematics - that it increases the legitimacy of the computer science profession rather than used for its practical value (Grundy 2000). “The prestige of a science often depends on its degree of mathematization, and the more math required for a particular job, the higher the pay and the lower the rate of women’s participation” (Schiebinger 1999, p.171). Some also believe that math has been used as a “weeder” to limit program enrolment or as a professor of mathematics at the University of Toronto claimed in 1980:

> The main function of mathematics in advanced capitalist society is the maintenance of social stratification. The aridity of our courses, their remoteness from students’ human concerns—together, of course, with their difficulty—make them especially forbidding hence specially good as selectors of students with superior capacity for self discipline (sometimes called repression) (Hacker 1990, p. 139).

Consequently, the following questions should be examined in more detail:

- What are the links between mathematics and the skills necessary to succeed in IT educational programs and as an IT professional?
- Is mathematics the only or most useful predictor of success in IT educational programs or as an IT professional?

- Are there other factors that can also serve as predictors of success, which are less likely to exclude women?
- What are the factors that reinforce the use of mathematics as an entry barrier to IT programs and the profession?
- What is the impact of mathematics as a barrier to entry on the participation of women?
- Are there other "gendered" aspects of the teaching of mathematics that can be addressed?

2. A CASE STUDY

The impact of mathematics as an entry requirement may have had a profound influence on the redevelopment of one undergraduate program in information technology management. The School of Information Technology Management at Ryerson University in Toronto, Canada was created through the merging of two programs - Administration and Information (AIM) on the one hand and Business Information Systems on the other. The final curriculum was not substantially different than AIM although the positioning in the marketplace was different. At the curriculum level it involved 3 basic changes. Most of the 41 courses required for graduation remained the same with a couple of exceptions:

- the addition of a compulsory programming course
- the addition of a compulsory finance course

In addition, a higher-level math (grade 13 or OAC) was added to the entry requirements. Although the empirical evidence linking performance in grade 13 math with performance in the program was unclear (Ho, 1998), it was felt that mathematics must be included as a requirement in order to legitimize the program as a Bachelor of Commerce (BCom) degree.

In 1999, the first year of the new program and the last year of the AIM program, the math entry requirement was 'preferred' but not required. In that year, as in previous years, women remained the majority (58%) of the incoming AIM students but fell to 39% of the incoming ITM students. In the following year (2000/2001), when math became a requirement, the proportion of females in the full-time ITM program fell to 35%.

The proportion of women in tenured and tenure track positions in the new school of ITM also declined from a dominant majority in the AIM program (8 of 12) to a slight majority in the merged ITM/BIS program 1999/2000 (9 of 16) to a minority in 2001/2 (6 of 18 faculty). However the majority of these women (5 of 6) had completed PhDs compared to a minority of the male faculty (4 of 11). All the men had higher than grade 13 math or equivalent compared to 1/2 of the women.

3. PILOT PROJECT

In summer 2002, ITM conducted a small pilot project to determine if mathematics proficiency is a necessary requirement and/or predictor of success for the ITM program and by extension success as an IT professional.

Goals

The goal of the Math Challenge program is to increase ITM's diverse applicant pool by providing an alternative point of entry to IT for students who may not have the required math prerequisites. It will also examine whether the mathematics requirement may serve as an unintended barrier to female students who would otherwise succeed in the program (and profession).

Design

Existing programs at other institutions were reviewed, (University of Toronto, 2002; University of British Columbia, 2002; University of Saskatchewan, 2002) and an intensive two week, 70-hour course was developed. The course was held from June 24-July 5 2002, and was designed to give students a necessary review in OAC (grade 13) math skills, but more importantly to prepare them for the math skills required in the ITM program. It was an instructor led course and students received additional support in the form of math tutors. They will also receive extra tutoring support during the school year.

Previous research and program evaluation has provided us with some core strategies in helping to encourage girls in math. For example, the use of real-world examples, student-led activities, collaborative environments and female role models are common program strategies (Clewell et al., 2000; Expanding Your Horizons, 1999; Campbell and Seinbrueck, 1996). Math and science experiences that include hands-on problem solving also appear to be a positive factor for girls (Burkam et al., 1997). Females also have been found to prefer learning about technology applications rather than technology bits. Consequently each of these strategies was included in our overall program design.

The program reviewed core math concepts, provided real world applications of those concepts and had a strong emphasis on visual learning. The program also included guest lectures (first year ITM professors) so as to prepare students for the material they would encounter in the ITM curriculum. Course design also allowed for integration of music, art and design to develop math concepts from a non-traditional perspective. The curriculum also heavily integrated the use of technologies to teach math in an innovative visual-oriented manner in a computer supported, collaborative learning environment. The design also focused on female-centered teaching methods in order to accommodate alternative learning styles. Some of the relational teaching strategies included:

1. Connect mathematics, science, and technology to the real world.
2. Choose metaphors carefully and have students develop their own.

3. Foster an atmosphere of true collaboration.
4. Encourage girls/students to act as experts.
5. Give girls/students the opportunity to be in control of technology.
6. Portray technology as a way to solve problems as well as a plaything.
7. Capitalize on girls' verbal strengths.
8. Experiment with testing and evaluation.
9. Give frequent feedback, and keep expectations high.
10. Experiment with note-taking techniques (Pollina, 1995)

Instructor
An instructor for the program was selected who had solid pedagogical expertise along with knowledge of female-centered approaches to learning and background in visual math techniques. She is also an expert in integrating new technologies into the math curriculum.

Admission Policy and Student Background
The program was designed for high achieving high school graduates without the mathematics credit normally required for admission to the undergraduate BCom in ITM. Although the program was approved in January 2002, a variety of factors resulted in it not being publicized in the high schools until late April 2002, well after the deadline for selection of university programs. Owing to the late announcement of the program, the admission standards were lowered in order to ensure adequate participation (see table 1) and this may have a negative effect on the long-term performance of students admitted. Students were required to pay a non-refundable fee of $150 (Cdn.) and were offered admission to the ITM program contingent on successful completion of the program. The first cohort included 11 students: 7 females and 4 males. Of these, 6 had averages of B+ or better. An additional 5 students were admitted whose grades ranged from 72.3% - 75.5%. Many candidates had strong backgrounds in subjects such as Music, English, Law, and Environmental Studies. All participating students were asked to perform a Math Skills Pretest to determine their level of math ability before the program. The test incorporated material from the standardized SAT I: Reasoning test along with math readiness and review questions. At the end of the program, students were retested to assess the change in their core math skills.

Table 1: Background Information and Gender Breakdown

Student Name	Gender	Average best 6	Math Grade	Highest and Lowest Grade	Comments
AA	Female				Mature student
BB	Male	72.3%	Dropped math	History 80% English 65%	
CC	Male	81%	NMR Dropped math	Geography 93% Accounting 71%	Was taking math correspondence course
DD	Female	78.3%	Calculus 38% Finite 54%	Geography 90% English 73%	
EE	Female	75.3%	Calculus19% Finite 53%	Admin Studies 80% Law 80% Economics65%	
FF	Female	82.3%	NMR	Music 88% Admin Studies 70%	
GG	Female	77%	Algebra 44% Calculus 39%	Music 91% English 79% Accounting 65%	
HH	Male	78.7%	51%	Law 82% Environ. Studies 71%	
II	Female	82.2%	No OAC math	Computers 91% French 57%	Was going to take math in summer school
JJ	Female	75.3%	Calculus 18% Finite 63%	Music 92% English 72% Economics 60%	Chose to take the program even though she had minimum math req.
KK	Male	75.5%	NMR*	P&H Ed Socio-Scien 90% Economics 45%	

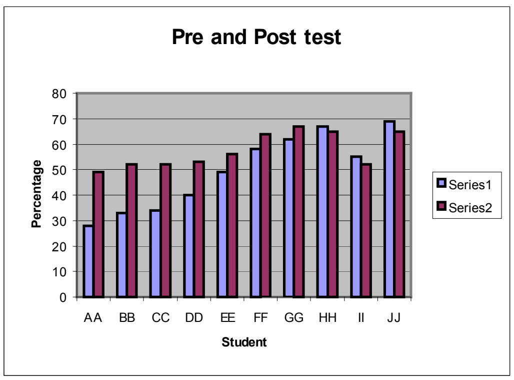
*NMR = No Mark Recorded

Resources
Materials for the course included a text on Data Management (Canton et. al. 2002) as well as Microsoft Excel and LiveMath: Computer Algebra and Graphing software.

Student Learning Objectives
- To help students review core OAC math concepts and understand real world math applications.

- To increase students' use of mathematical language and reasoning skills and increase their confidence in their math ability.
- To have students study and understand the relevance of math concepts as they relate to first year university courses including Accounting, Finance, Programming, Economics and Statistics.
- To increase technological ability by familiarizing students with software including webified computer algebra and graphing tools and spreadsheet software (LiveMath and Microsoft Excel).

Findings
Generally student performance on the entrance test improved as a result of the program. Of the 11 students, 10 attended all classes. Seven out of 10 or 70% of students improved their test score. The average increase for the class was 23%, but there was a significant range (standard deviation was 41). One student improved by 75% while another decreased by 7%. However, while 5 of 10 students scored over 50% on the pre-test, 9 of 10 scored 50% or higher on the post-test. (See Table 2 and figure below)



*One student (KK) who did not meet the entry requirements but was admitted at the request of the admissions department missed several classes and demonstrated a significant decline in test scores. This student's scores were excluded from the results.

Table 2: Test Results

Student	Pre-test %	Post-test %	% change
AA	28	49	75
BB	33	52	57
CC	34	52	52
DD	40	53	32
EE	49	56	14
FF	58	64	10
GG	62	67	8
HH	67	65	-4
II	55	52	-6
JJ	69	65	-7
			231
		Average % change	**23.1**
		Standard deviation	**41**

Student Feedback
Students were asked to complete a simple questionnaire. The majority rated the program and the instructor as excellent. (See Table 3)

Table 3: Student Evaluation of the Program

Category	Excellent	Good	Acceptable	Poor
Usefulness of content	60%	40%		
Effectiveness of Instructor	80%	20%		
Effectiveness of tutors	100%			
Effectiveness of software	50%	50%		
Overall effectiveness of program	90%	10%		

n=10

When asked, "Do you think this program helped improve your math confidence or ability?" 100% of the student participants answered yes.

Specific comments students made about the program included:

- "great use of technology and a big difference from high school math as far as usage of technology…considered a real advantage"
- "program showed how math was related and applicable to course material for next year"
- "consider the program to be very innovative"
- "increased confidence in using software i.e. spreadsheets etc."
- "liked evaluation through assignments rather than tests"
- "great support..always someone there to help you work through the problems"
- "very well organized program"
- "liked that everything was visual…easier to learn math that way
- "great to be taught how to use the tools to help you work through the math".

Instructor Feedback
Specific assessment by the Instructor suggests that the program was successful in meeting its learning objectives and that students increased their technological skills and mathematical reasoning. When asked, "How could the program be improved?" Both students and Instructor felt that the program should be longer (at least 3-4 weeks in order to cover the abundance of material). Students would like more real life examples implemented into the curriculum. Student and instructor agree that there should be more material in the curriculum that relates the math more directly to course material next year i.e. Economics, Business, etc. and recommended that the organizers

encourage more guest lecturers from the ITM program.

Program Assessment

By the end of this small pilot study, it was apparent that the program was a successful learning environment and a positive experience for both Instructor and participating students. The pilot also achieved its goal to increase the diverse applicant pool by providing an alternative point of entry to 11 students who did not have the required math prerequisites. This addition will serve to enhance the multidisciplinary nature of the IT management degree program. It also appears promising that even a short-focused summer bridging program can improve student's performance on standardized math tests as well as to increase their interest and confidence in mathematics. However, the real measure of the success of the program will be to evaluate student performance in the ITM degree. The critical next phase of the evaluation will be to track each student's performance in years 1, 2, 3, and 4 and will compare student performance to regular students with comparable averages and mathematics. Both performance and attrition will be tracked. The next phase will include a matched analysis of the program participants to students with similar GPA and acceptable math scores. Although the sample size is too small to be definitive, it is expected that, if performance of the first cohort of students is acceptable and if resources are provided, the program will be run with a larger group next summer.

4. LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This paper has raised a number of questions regarding the role mathematics plays as a barrier to entry and predictor of success in Information Technology educational programs and careers. It has also described the impact that an increase in mathematics requirements has on the participation of women in an IT management undergraduate degree. It also reviews the rationale and content for a program aimed at providing high performing students who lack conventional mathematics education with the skills needed to succeed in an IT management program. Despite its limitations, this small pilot project raises some interesting issues that need further exploration. Whether or not students completing the program will be as successful in the ITM program as students with more traditional mathematics education remains to be seen. A larger scale pilot project coupled with longer-term tracking and evaluation is needed.

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